REPLACEMENT OF CEMENT USING FLY ASH

Minor project Submitted

By

DIPLOMA STUDENTS 5th semester

Under the Supervision of

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I hereby forward the project entitled “**Replacement of cement in concrete using fly ash**” done by

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under my supervision in partial fulfilment of the requirements for the course in the Department of Civil Engineering.

ACKNOWLEDGEMENT

We hereby convey our sincere respect, thanks and heartily gratitude to our mentor cum advisor **PRASHANT KUMAR** for his immense support , monitoring and guidance .This mini project would never have been completed without his constant help and encouragement .The blessing , help and guidance given by him time to time shall carry us a long way in the journey of our lives .

Lastly, we thank almighty, our parents and friends for their constant encouragement without whom this project would not be possible.

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PERSONAL ACCOUNT

- **WHY WE CHOOSE THIS TOPIC:** - In the current situation of huge wastages from coal industries are harming all of us. So, we thought that how we can use the wastages. Then we search about the properties of fly ash and we found that it can be use as a replacement of cement in concrete. And also at the time of lockdown as we can't go outside our residence and meet with our groupmates, so we thought that we can make project on this without going outside as some data is available on the internet.

- **HOW WE WORKED IN GROUP:** - After selecting the topic and confirming from our supervisor Bharat Bhushan we made some conference phone calls to discuss about where to start and what difficulties we can face and how to tackle them. Then in the next conference meeting we sub divided the total project between us. We all done search on our topics and make individual documents and collected and edited by both Yash Raj.

- **CHALLENGES WE FACED:** When we started the project, 1st of all we faced the problem that sufficient resources and materials for the project.

  Secondly, as we cannot go outside of our home to we are unbale to make a face to face discussion that makes a big effect on our project.

  Third, we are not in the campus so, we are unable to make any practical experiment on these topics.

Fourth, we don't have completed our concrete technology syllabus so we have to make that up to what we need for this project.

These challenges we faced during the project work.

- **WHAT MADE US HAPPY AND SAD:** The main point that made us happy is, when we do through the difficulties then at every point we get something to learn.

  When we are want to do some experiment and but due to unavailability of all resources we are unable to do that. This made us sad.

Abstract:

Key words: Concrete, Fly Ash. Cement, Fine Aggregates, Workability, Durability, Permeability, Compressive Strength.Concrete is the most used construction material around the world. It is a composite material made of water, cement, coarse and fine aggregates. However the production of raw materials for concrete has a huge influence over the environment since it is one of the largest industries. Significant amount of energy and natural resources are used followed by emission of greenhouse gases.

Aggregates constitute more or less 70 - 80 % of the concrete and the remaining 20 -30% constitutes water. These have a direct impact on the mechanical properties of the concrete. Replacing the raw materials used for its production, with waste products from different industries will not only help in reduction of use of natural resources but also in reducing emission. Hence, this project has focussed on

evaluating feasibility of using waste material like fly ash as an alternative for cement.

Fly ash is a waste material that is produced as a byproduct of combustion of coal. It has similar physical and chemical characteristics like cement, hence can be allowed to be used in concrete after its effects on mechanical properties like compressive strength on concrete is clear.

Results of tests performed on concrete containing proportion of fly ash with cement were taken and it was seen that there was considerable improvement in compressive strength and other mechanical properties of concrete.

CHAPTER 1:

INTRODUCTION

1.1 Background:

Concrete is one of the most significant items that is used in construction, worldwide. It is basically a composite material composed of fine and coarse aggregate bonded together with a fluid cement (cement paste) that hardens over time.

The demand of concrete is increasing worldwide at an alarming rate, hence the demand of cement and aggregates are also increasing. To provide alternative sources as a replacement of cement is a challenge in itself. With the world advancing rapidly, waste management has become one of our biggest concerns right now. Using industrial wastes as alternative sources in production of concrete would be really beneficial as it will reduce the intensive usage of natural resources as well as reduce the pollution caused due to emission of gases.

There are many industrial waste products having the potential of replacing the aggregates in concrete In this project we are mainly going to discuss how fly ash can be used as an alternative for Portland cement.

1.2 Scope:

The purpose of this project is to determine whether fly ash can be used in production of concrete or not and to determine the way it can affect the mechanical and chemical properties of concrete.

1.3 Aims:

The following objectives were met and thoroughly discussed.

- Background information about production of fly ash, and it's physical and chemical properties.
- Effect on permeability of concrete.
- Effect on Strength of Concrete.
- Effect on Durability and Workability of Concrete.

1.4 Outline:

The first chapter is an introduction which addresses the topic , the reason for choosing this topic and scope of research.

The second chapter includes a review of the literature, it discusses the effects on concrete after using fly ash.

The third chapter is a conclusion which summarises everything.

Chapter 2:

2.1 Production of Fly Ash:

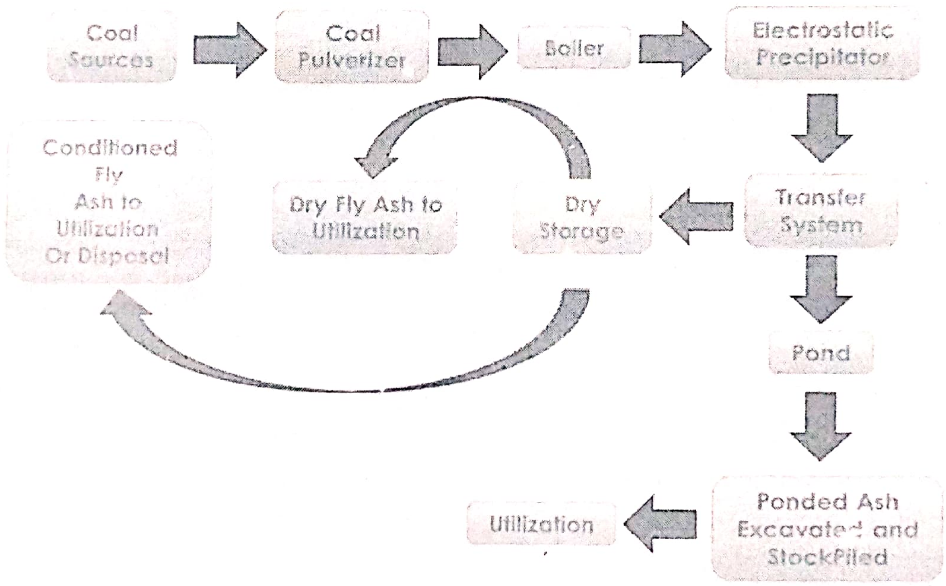


Fig 2.1.1: PROCESS OF PRODUCTION OF FLY ASH

Fly ash is the finely divided residue that results from the combustion of pulverized coal and is transported from the combustion chamber by exhaust gases.

Fly ash is produced by coal-fired electric and steam generating plants. Typically, coal is pulverized and blown with air into the boiler's combustion chamber where it immediately ignites, generating heat and producing a molten mineral residue. Boiler tubes extract heat from the boiler, cooling the fuel gas and causing the molten mineral residue to harden and form ash.

Coarse ash particles, referred to as bottom ash or slag, fall to the bottom of the combustion chamber, while the lighter fine ash particles, termed fly ash, remain suspended in the fuel gas. Prior to exhausting the flue gas, fly ash is removed by particulate emission control devices, such as electrostatic precipitators or filter fabric baghouses.

2.2 Physical Properties of Fly Ash:

Before getting into the fly ash in concrete part we first have to know about the physical properties of fly ash. Some physical properties of fly ash is given below.

a. Fly ash consists of fine, powdery particles predominantly *spherical in shape*, either solid or hollow, and *mostly amorphous in nature.*

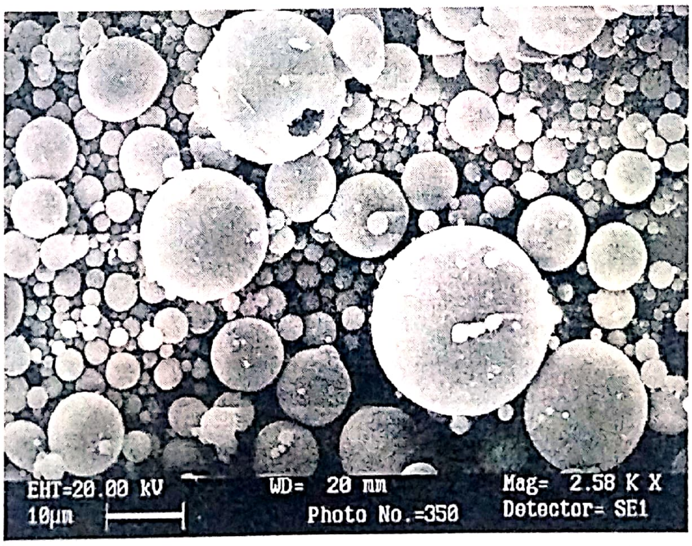


Fig 2.2.1 MICROSCOPIC VIEW OF FLY ASH

b. In general, the specific gravity of coal ashes lies around *2.0* but varies to a large extent, from 1.6-3.1. This variation is due to a combination of several factors such as *particle* *shape, gradation, and chemical composition*. Based on the grain size distribution fly ashes can be classified as *sandy silt* to *silty sand*. Particularly, Indian coal ashes are predominantly of silt-size, with some clay-size fraction. Fly ash has high specific surface area and low bulk density.

c. The amount of unburned carbon and iron impact the colour of fly ash, which can vary from *orange* to *deep red*, *brown*, or *white* to *yellow*.

d. The specific gravity and *the fineness of the fly ashes increased* with an *increase in the grinding time*. However, this increase was less significant beyond 2 h. The morphology of the fly ashes was changed by grinding. Most of the pedospheres and large, irregular-shaped particles were crushed after 2 h of grinding. However, the *number of the spherical particles reduced with increased grinding*.

2.3 <u>Chemical Composition of Fly Ash:</u>

Fly

Component	Bituminous Coal	Sub bituminous Coal	Lignite Coal
SiO2 (%)	20-60	40-60	15-45
Al2O3 (%)	5-35	20-30	20-25
Fe2O3 (%)	10-40	4-10	4-15
CaO (%)	1-12	5-30	15-40
LOI (%)	0-15	0-3	0-5

ash consists primarily of *oxides of silicon*, *aluminum iron* and *calcium*. *Magnesium*, *potassium*, *sodium*, *titanium*, and *sulfur* are also present to a lesser degree. The different parts of fly ash is given in the table below.

Table 2.3.1 CHEMICAL COMPOSITION OF FLY ASH

2.4 Classification of Fly Ash:

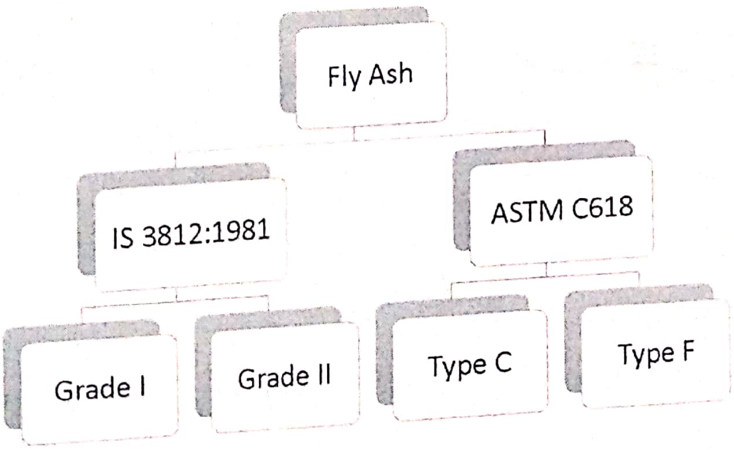


Fig 2.4.1: CLASSIFICATION OF FLY ASH

When used as a mineral admixture in concrete, fly ash is classified as either *Class C* or *Class F* ash based on its chemical composition. American Association of State Highway Transportation Officials (*AASHTO*) M 295 [American Society for Testing and Materials (ASTM) Specification C 618] defines the chemical composition of Class C and Class F fly ash. Based on oxides content in fly ash is classified in to two types by Indian Standards (*IS 3812:1981*). Those are *Grade I* and *Grade II*.

1. **Type of Fly Ash As Per IS Codes (IS 3812-1981)**

A. Grade I:

This grade of Fly ash is derived from bituminous coal having fractions $SiO_2+Al_2O_3+Fe_2O_3$ greater than 70 %.

B. Grade II:

This grade of Fly ash derived from lignite coal having fractions $SiO_2+Al_2O_3+Fe_2O_3$ greater than 50 %.

2. **Type of Fly Ash As Per American Society for Testing and Materials (ASTM C618)**

Depending on the type of coal and the resultant chemical analysis, ASTM has classified fly ash into two types,

A. Type C:

Class C ashes are generally derived from sub-bituminous coals and consist primarily of calcium alumino-sulfate glass, as well as quartz, tricalcium aluminate, and free lime (CaO). Class C ash is also referred to as high calcium fly ash because it typically contains more than 20 percent CaO.

B. Type F:

Class F ashes are typically derived from bituminous and anthracite coals and consist primarily of an alumino-silicate glass, with quartz, mullite, and magnetite also present. Class F, or low calcium fly ash has less than 10 percent CaO.

2.5 Permeability of Concrete:

2.5.I Dependence of Permeability of Concrete:

► *Permeability is defined as the property that governs the rate of flow of a fluid into a porous solid.*

If the concrete is impermeable than corrosive agents cannot penetrate and attack it. Concrete has small pores whose diameter varies from 0.01 to 10 micron in cement pastes while it may be between 1 mm to 10mm when cement paste is laid over the aggregate.

Factors affecting permeability of concrete: -

i. Water-Cement Ratio
ii. Improper Compaction of Concrete
iii. Improper Curing
iv. Age of concrete
v. Pore structure
vi. Degree of compaction

And that is why if concrete is used for water retaining structures, waterproofing membranes are applied. This is the case for basement walls, and concrete storage tanks in reinforced concrete. Roof decks should also be covered with waterproofing membranes to prevent water seepage.

2.5.II Effect of Fly Ash on Permeability of Concrete :

The decrease in water content combined with the *production of additional cementitious compounds reduces the pore interconnectivity of concrete*, thus decreasing permeability. The influence of fly ash on relative permeability of concrete with replacement of cement by fly ash is shown in table 2.5.1 with

Fly ash		W/(C+F) by Weight	Relative Permeability, %	
Type	% by weight		28 Days	6 Month
None	-	0.75	100	26
Chicago	30	0.70	220	5
	60	0.65	1410	2
Cleland	30	0.70	320	5
	60	0.65	1880	7

different percentage.

It is clear from these results that the permeability of the concrete was directly related to the quantity of hydrated cementitious material at any given time. After 28 days of curing, at which time little pozzolanic activity would have occurred, the fly ash concretes were more permeable than the control concretes. *At 6 months*, this was

Table 2.5.1 RELATIVE PERMEABILITY OF CONCRETES WITH AND WITHOUT FLY ASH

reversed. *Considerable imperviousness had developed*, presumably as a result of the pozzolanic reaction of fly ash. Diffusion of chloride ions into Portland blended cement paste is found *44.7× 10-9 cm2/sec*. and it was found in *fly ash/Portland cement paste 14.7× 10-9 cm2/sec*. hence *permeability of the concrete decreases*. When fly ash is added to concrete, the permeability is significantly lower as shown in *figure 2.5.1*. This reduces the transportation rate of chloride ions, and many other materials, into concrete.

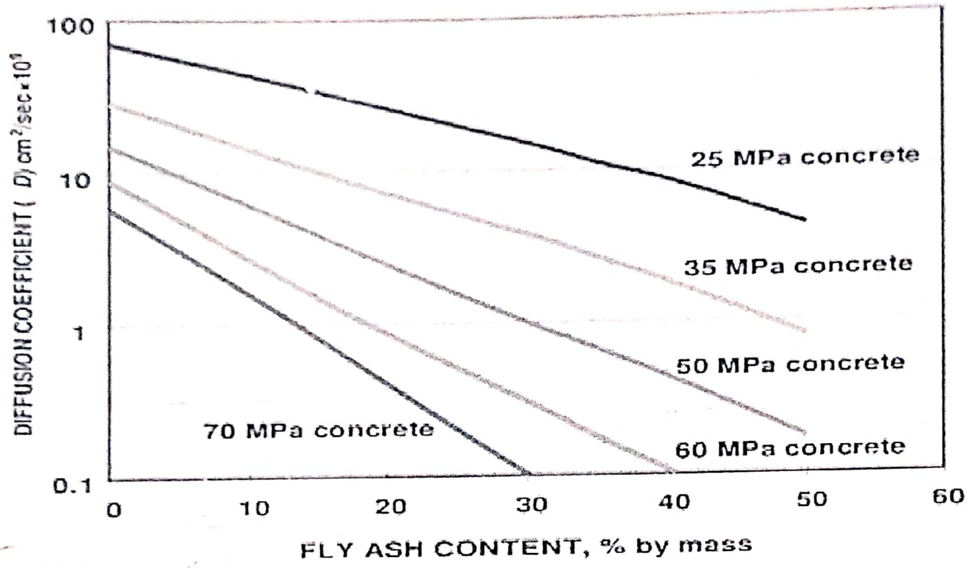


Fig 2.5.1 ESTIMATION OF CHLORIDE DIFFUSION COEFFICIENT WITH FLY ASH CONTENT OF CONCRETE FOR DIFFERENT STRENGTH OF CONCRETE.

2.5.III <u>Rapid Chloride Permeability Test (RCPT):</u>

The penetration of chloride ions is measured by *Rapid Chloride Permeability Test (RCPT)*. The RCPT is a measurement of the electric charge that travels between two sides of a concrete specimen *over a six hour period*. This charge is correlated to chloride ions travelling the pore system. Lower values signify a higher resistance to chloride intrusion. The test shown in *figure 2.5.2* is used as a measure of durability of hardened concrete

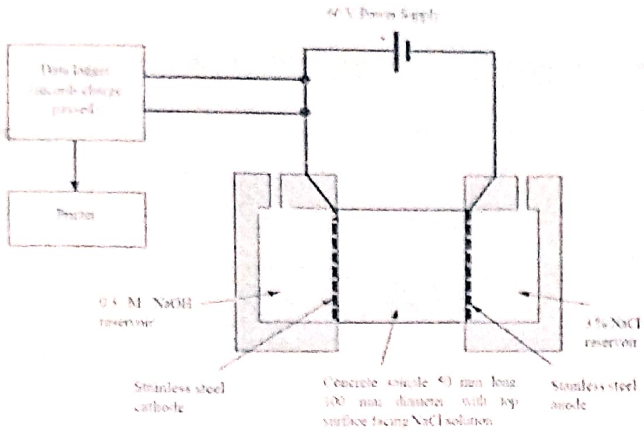


Fig 2.5.2 RCPT setup

► **Procedure & Results:**

a. A specimen *50 mm thick* and *100 mm diameter* concrete disc from concrete member meant for durability measurement, is subjected for *6 hours to direct electrical current having potential difference of 60 volts.*

b. The test specimen is inserted between two chambers- one filled with a *3 % NaCl solution as the chloride ion source* and the other with *0.3 M NaOH to serve as the positive terminal.*

c. The quantity of chloride ions migration is counted from the count of the total charge passed during 6 hours test period.

d. From the charge passed in RCPT through the plain concrete, is classify in different chloride permeability categories as shown in table below.

Chloride Ion Penetrability	Charge Passing Coulombs	Typical Concrete Type
High	> 4000	High W/C ratio (>0.6)Conventional PC Concrete
Moderate	2000-4000	Moderate W/C ratio(0.4-0.6)Conventional PC Concrete
Low	1000-2000	Low W/C ratio(< 0.40) Conventional PC Concrete
Very Low	100-1000	Latex Modified Concrete, Internally Sealed Concrete.
Negligible	< 100	Polymer impregnated concrete polymer concrete

Table 2.5.2 RATING OF CHLORIDE PERMEABILITY OF CONCRETE ACCORDING TO THE RCPT

The effect of fly ash on pore solution was studied by Shi. A *replacement of 20 % cement* with fly ash decreased the specific conductivity of pore solution by approximately *20 % to 25 % at 28 days*, and approximately *30 % to 40 % at 550 days*, while *40 % replacement decreased the alkali concentration in pore solution by 35 % before 28 days* and approximately after 28 days.

In order to assess the permeability of concrete, *VPV content test was conducted*. This test *measures the capillary pores, gel pores, air voids and microcracks in concrete specimens*. The relationship between the *fly ash content* and the *VPV* is shown in *Fig. 2.5.3*. It can be seen that *after 28-d of curing*, VPV is within a range of *7.8–9.2%* for all the mixtures. *With the addition of fly, the VPV reduced gradually*. After 180-d of curing, the permeable voids significantly reduced for all mixes. Due to the hydration of the binder, the capillary and gel pores of the concrete paste reduced. Furthermore, with the addition of fly ash, the permeable voids decreased gradually. *After 6 months of curing the permeable voids were 6.6, 6, 5.8, 5.2 and 5.1% respectively for the samples with 0, 10, 20, 30 and 40% fly ash content*. The *higher fineness* and *ball bearing* effect of fly ash particles reduce the pores in the fly ash concrete. Thus VPV declined with the increment of fly ash content.

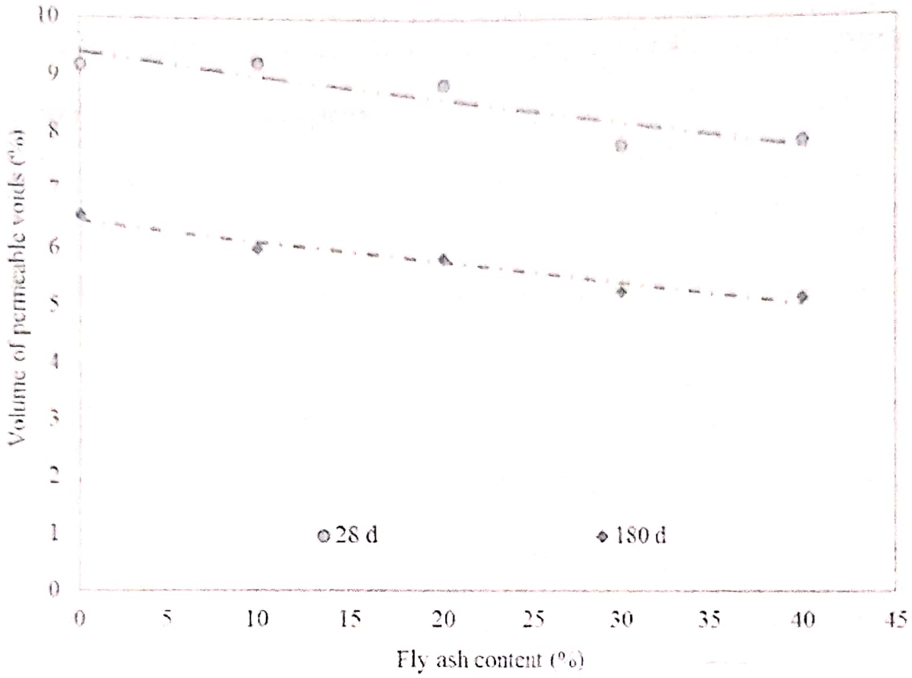


Fig 2.5.3 EFFECT OF FLY ASH ON VOLUME OF PERMEABLE VOIDS.

Oxygen permeability tests were carried out on plain ordinary Portland cement (OPC) and fly ash concretes at three nominal strength grades. Prior to testing the concretes were subjected to a wide range of curing and exposure conditions. The results emphasize the importance of adequate curing to achieve concrete of low permeability, especially when the ambient relative humidity is low. In addition, the results demonstrate the considerable benefit that can be achieved by the use of fly ash in concrete. Even under conditions of poor curing, fly ash concrete is significantly less permeable than equal-grade OPC concrete, the differences being more marked for higher-grade concretes. Attempts were made to correlate strength parameters with permeability but it is concluded that neither the strength at the end of curing nor the 28-day strength provides a reliable indicator of concrete permeability. A reliable correlation was established between the water to total cementitious material ratio [w/(c+f)] and the permeability of concretes subjected to a given curing and exposure regime.

2.6 Variation of Strength in Concrete After Using Fly Ash:

One of the primary benefits of fly ash is its reaction with available lime and alkali in concrete, producing additional cementitious compounds. The following equations illustrate the pozzolanic reaction of fly ash with lime to produce additional calcium silicate hydrate (C-S-H) binder:Cement Reaction:

C3S + H → C-S-H (gel) + CaOH

Pozzolanic Reaction:

CaOH +S → C-S-H (gel)

2.6.1 Variation of Ultimate Strength:

The additional binder produced by the fly ash reaction with available lime allows fly ash concrete to continue to gain strength over time. Mixtures designed to produce equivalent strength at early ages (less than 90 days) will ultimately exceed the strength of straight cement concrete mixes.

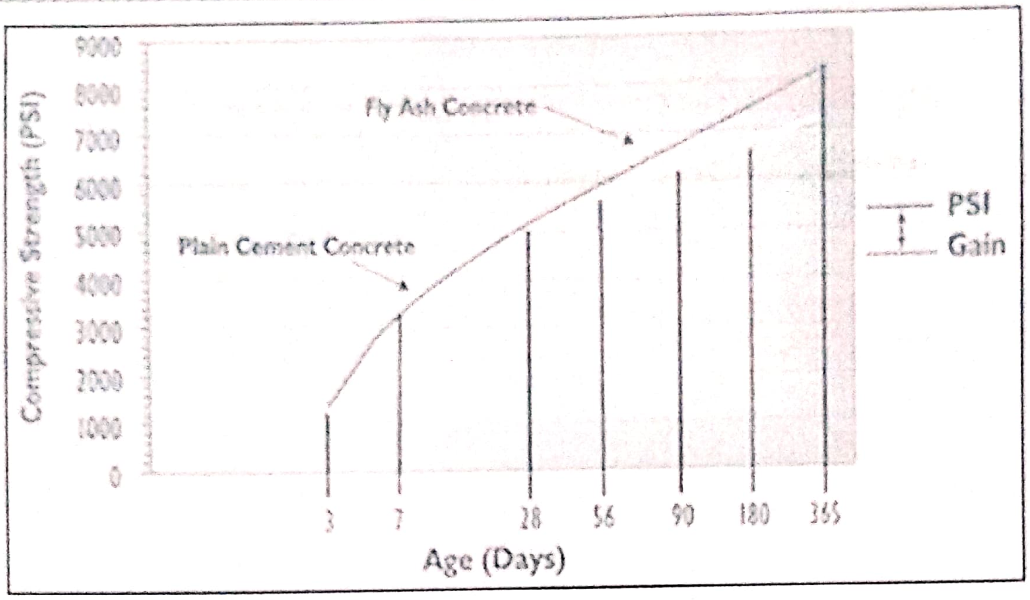


Fig 2.6.1 COMPRESSIVE STRENGTH OF PLAIN CEMENT CONCRETE

Based on experimental results, mathematical models were elaborated to predict the development of compressive strength of concrete with fly ash replacement percentages up to 30 %. Strength of concrete with different types of cement (CEM I 42.5, CEM I 32.5, CEM III 32.5), after 2, 28, 90, 180 days of curing, have been analysed to evaluate the effect of addition content, the time of curing and the type of cement on the compressive strength changes.

Some of the results from experiments performed by Dr. Marta Kosior-Kazberuk and Dr. Małgorzata Lelusz are shown below:

▶ Tests were carried out for concretes contained three types of commercial cement:

Two sorts of Portland cement CEM I 42.5 R (C1), CEM I 32.5 R (C2) with different mineral composition and blast-furnace cement CEM III/A 32.5 NA (C3).Furnace slag used in cement C3 contained 8 % CaO; 39,1 % SiO_2; 7,1 % Al_2O_3; 1,7 % Fe_2O_3; 0,23 % SO_3; 6,2 % MgO. The content of slag in cement C3 was 62 %

From the experiments conducted, it was found that:

i)The fly ash addition, in considered range of FA/C values, has no significant effect on specific gravity and water absorption.

ii)The addition reduces the capillary suction of water, determined after 24 h test. The variation of flexural strength with curing time of concretes is presented in Figs given below.

iii)The graphs show that the rate of strength development of the concrete with fly ash is slower in comparison to that of the control specimens. The concretes containing additives reached greater values of flexural strength than control concretes.

iv)The changes in strength with age can be analysed in detail on the basis of percentage relative strength to 28 days strength, as shown in Tables given below

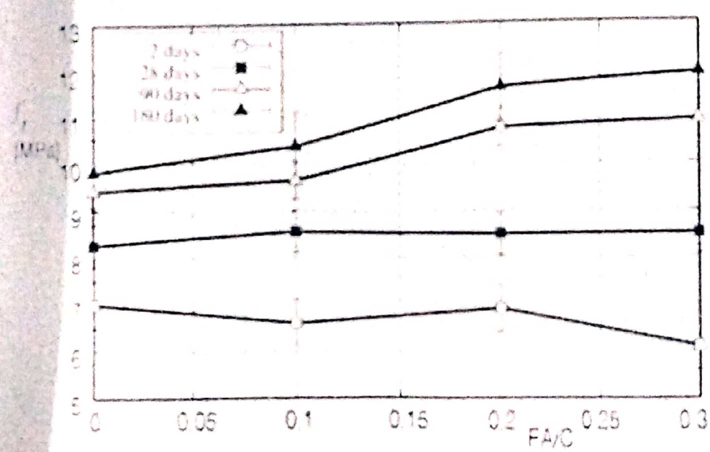


Fig 2.6.2 FLEXURAL STRENGTH DEVELOPMENT OF CONCRETE OF CEMENT C1

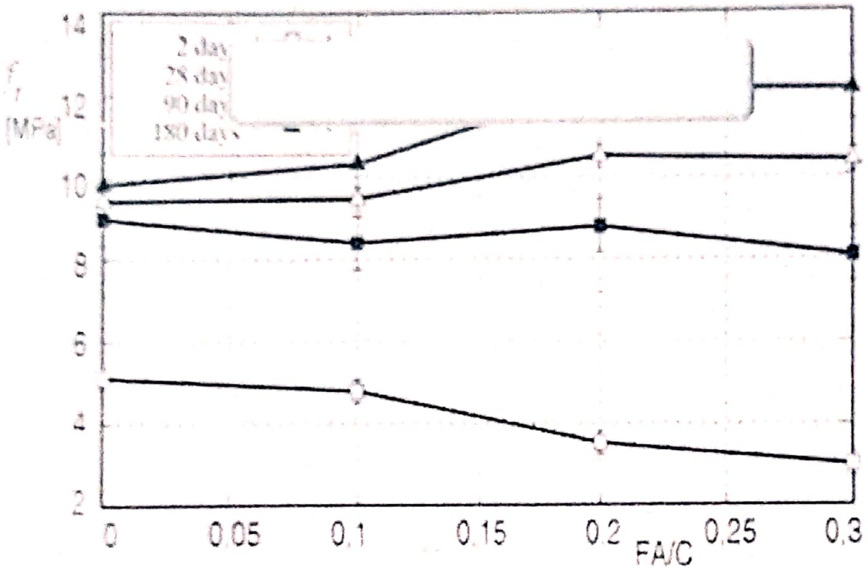


Fig 2.6.3 FLEXURAL STRENGTH DEVELOPMENT OF CEMENT C2 CONCRETE

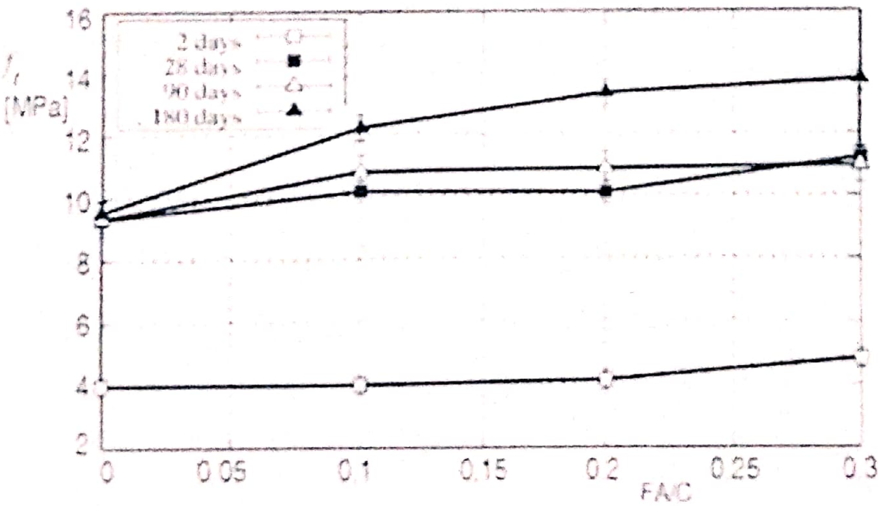


Fig 2.6.4 FLEXURAL STRENGTH DEVELOPMENT OF CEMENT C3 CONCRETE

The observed results of concrete strength test prove fly ash influence on the strength development at all ages.

I. The rate of strength development is lower for mixtures containing fly ash, at early ages. The rate of strength gain in concretes with fly ash is significant between 28 and 180 days.
II. The mixtures with C1 cement achieve the highest one and the mixtures with C3 cement achieve the lowest 28-days flexural strength in comparison with 28-days strength because of cements used for composition.
III. The increase in strength between 28 and 90 days of curing is the slowest for C3 cement (blast furnace cement) concretes, but after 180 days of storage the flexural strength of C3 cement concretes with fly ash is comparable with C2 cement concretes.

2.6.II <u>Variation of Compressive Strength:</u>

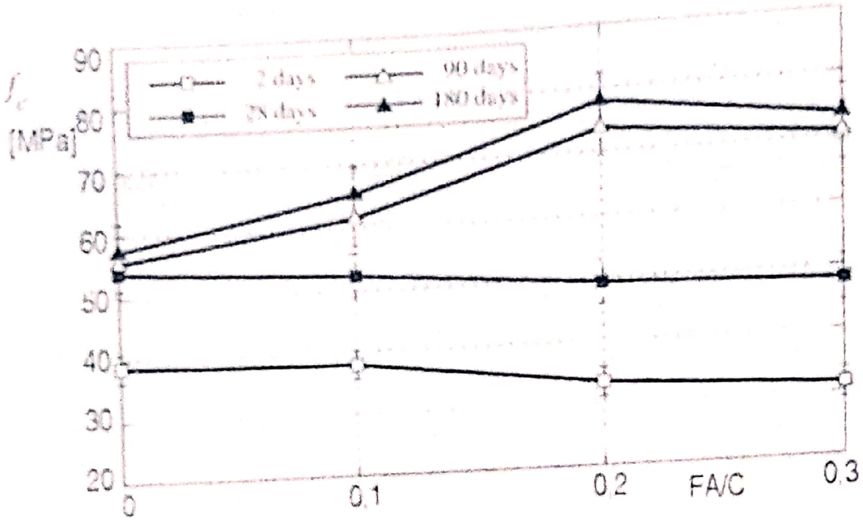


Fig 2.6.5 COMPRESSIVE STRENGTH DEVELOPMENT OF CEMENT C1 CONCRETE

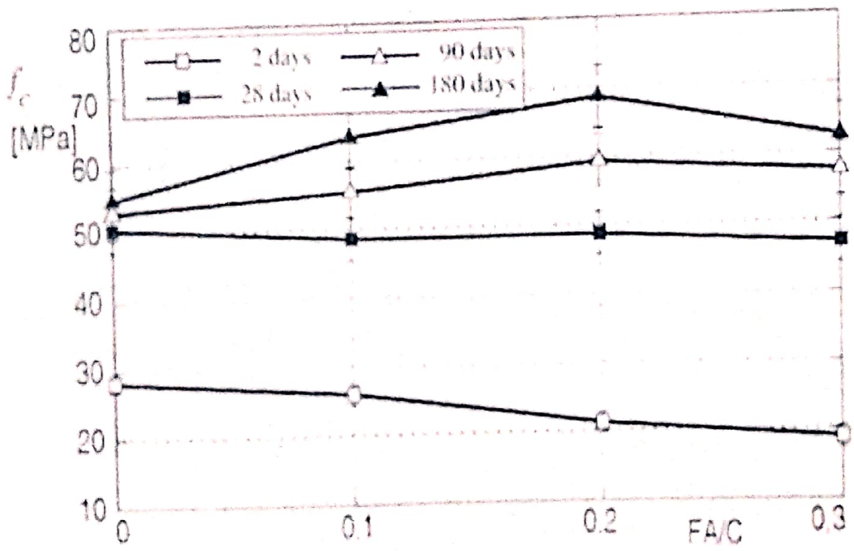


Fig 2.6.6 COMPRESSIVE STRENGTH DEVELOPMENT OF CEMENT C2 CONCRETE.

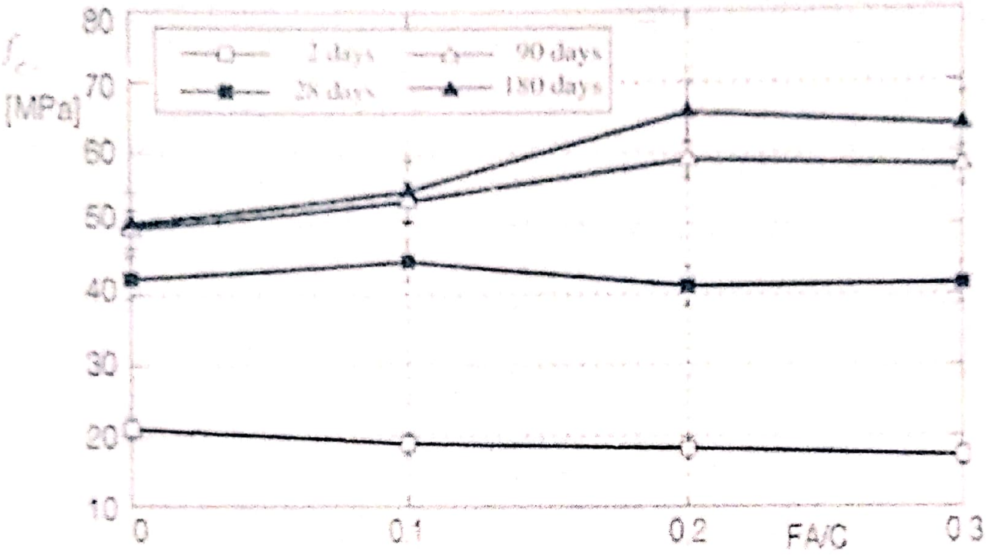


Fig 2.6.7 COMPRESSIVE STRENGTH DEVELOPMENT OF CEMENT C3 CONCRETE

The results obtained show that the fly ash has a beneficial effect on compressive strength of all cements tested. Although the rate of strength increase of fly ash concrete is slower and sustains for longer periods, the concretes containing fly ash are capable of developing a higher strength than portland cement concrete as well as the blast furnace cement concrete.

2.7 Effects of Fly Ash on The Durability of Concrete:

Fly ash is used in concrete as an admixture as well as in cement. The use of concrete in aggressive and potentially aggressive environmental condition has been increased substantially. Concrete structures are employed to support machineries, staffs, and products of oil and gas exploration and productions. Concrete structures used to keep nuclear reactor and need to contain gases and vapours that released at high temperatures and pressure in emergency situations. In all aforementioned conditions, fly ash utilization like cementitious materials play significant role.

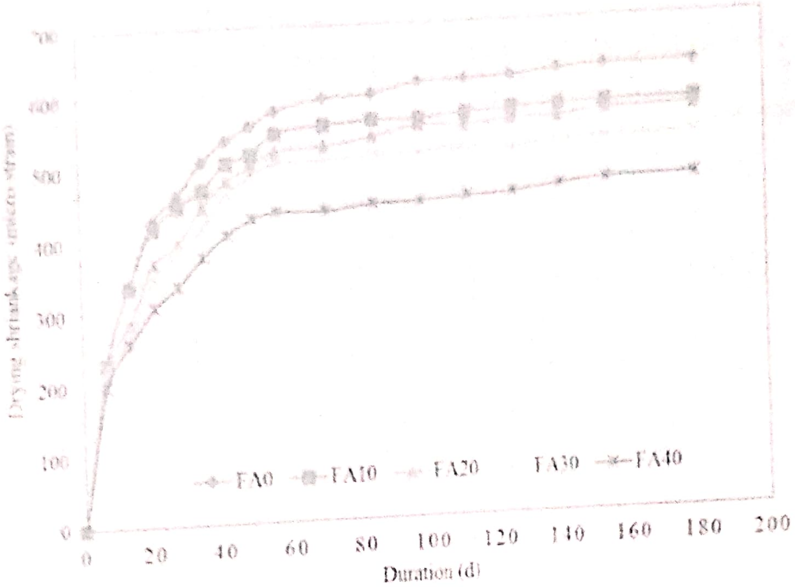
Following are the effects of fly ash on various durability parameters:

I. Carbonation of concrete
II. Durability of concrete subjected to repeated cycles of freezing and thawing
III. Abrasion and erosion of fly ash concrete
IV. Sulphate resistance of concrete
V. Alkali aggregate reactions in concrete
VI. The corrosion of steel reinforcement in concrete
VII. Concrete exposed to seawater.

Durability can be measured by these para meters,

→ Drying shrinkage
→ Microstructure observation

2.7.I Drying Shrinkage:



The figure 2.7.1 shows the impact of fly ash on the concrete

Fig 2.7.1 VARIATION OF SHRINKAGE WITH DIFFERENT FA % AGE

shrinkage. It is noticeable that, the majority of concrete shrinkage occurred in first two months. Afterwards, the shrinkage became steady for all the mixes. After 28-d of testing the drying shrinkage, the samples were 464, 450, 398, 389, and 340 micro-strains respectively for the 0, 10, 20, 30 and 40% fly ash mixtures. With the addition of 10, 20, 30 and 40% fly ash in the concrete, the shrinkage were 96, 85, 83 and 73% of the control mixes. After six months of curing the shrinkage of the samples were 631, 581, 571, 533, and 475 micro-strain respectively for 0, 10, 20, 30 and 40% fly ash mixtures; corresponding to about 92, 90, 84 and 75% of control concrete shrinkage. It is noticeable that, with the addition of fly ash, the drying shrinkage is reduced gradually.

It has been well established that, drying shrinkage of concrete depends on three controlling factors:

1. **Water–binder ratio of concrete**;
2. **The volume of paste in concrete**; and
3. **The rate of hydration**.

All the five mixtures in this study had the equal water–binder ratio as well as the paste volume. However, cement replacement by the fly ash reduces the lime content from the mix as the class F fly ash has a significantly low lime content. Due to the reduction of lime content, the rate of hydration of concrete reduces. As a result, fly ash concrete exhibits lower drying shrinkage compared to the conventional concrete.

2.7.II <u>Microstructure Observation:</u>

In order to evaluate the high durability of fly ash concrete microstructural features was investigated by SEM. The micro structural morphology of broken concrete with 40% fly ash as a binder (FA40) after 28-d of curing is shown in figure. It can be seen that ettringite needles begin to generate in the vacant space of the binder matrix, as well as on the fly ash surface. Smooth spherical fly ash particles are also noticeable, which indicates the hydration of fly ash in its initial phase. The partial shape of fly ash is spherical and the presence of the spherical particles in microstructure in concrete after 28-d of curing indicates that fly ash particle has not been reacted with the cement in the initial stage of hydration. The spherical shape of fly ash gradually decomposes in concrete and replaced by ettringite needles due to the exposure of aggressive environment. This supports the hypothesis that fly ash reduces the rate of hydration in concrete. The microstructure of FA40 after 180-d curing is given in. It can be seen that due to the pozzolanic reaction of fly ash, the spherical particles were replaced by ettringite. A large number of ettringite needles are noticeable in the voids between the aggregates. Besides, the ettringite needles are longer and filling the vacant spaces of the binder matrix. Thus, the pozzolanic reaction of fly ash contentiously fills the voids between the aggregates by the ettringite needles. Therefore, concrete containing fly ash creates a denser binder matrix compared to the conventional concrete.

(a) 28 d

(b) 180 d

Fig 2.7.2 MICROSTRUCTURE OF FLY ASH CONCRETE AFTER 28 DAYS AND 180 DAYS

2.8 Effects of Fly Ash on Workability of Concrete:

Fly ash particles are generally spherical in shape and reduces the water requirement for a given slump. The spherical shape helps to reduce friction between aggregates and between concrete and pump line and thus increases workability and improve pumpability of concrete. Fly ash use in concrete increases fines volume and decreases water content and thus reduces bleeding of concrete

In order to understand the influence of fly ash on workability of concrete the water content was set to be constant for all the different mixes. As the fly content is increased, the slump of concrete goes up. For instance, for the first mix (0% FA), the slump was about 87mm and 80mm for cement and sand replacement respectively and the concrete was very similar to the self-compacting concrete. It is also noticeable that the concrete mixes with fly ash replacement of cement are more workable than concrete mixes with fly ash replacement of fine aggregates. Therefore, it can be concluded that as the fly ash content increases in a concrete mix, the water demand is reduced.

The fineness and spherical shape of fly ash particles are the main physical properties that play a major role in improving the workability of a concrete mix.

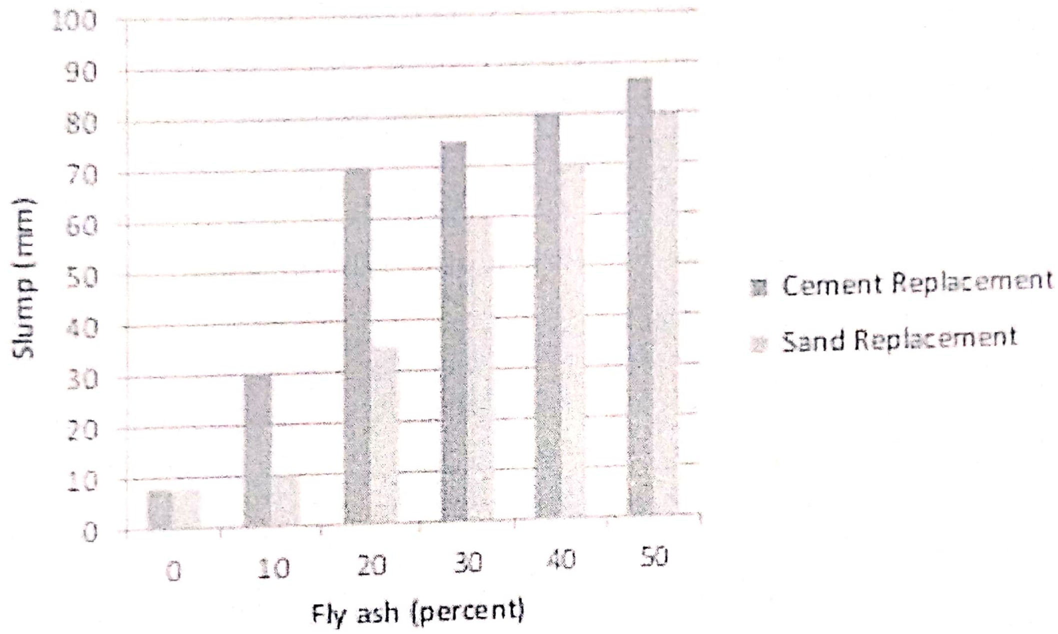


Fig 2.8.1 COMPARE BETWEEN SLUMP VERSUS FLY ASH PERCENTAGE AS CEMENT AND SAND

2.9

Advantages of Using Fly Ash:

The advantages of using fly ash far outweigh the disadvantages. The most important benefit is *reduced permeability* to water and aggressive chemicals. Properly cured concrete made with fly ash *creates a denser product* because the size of the pores are reduced. This *increases strength* and reduces permeability.

Today, there are at least two ways to make fly ash more beneficial: *a dry process that involves triboelectric static separation* and *a wet process based on froth flotation*. These procedures generally lower the carbon content and the LOI of fly ash. The cost of an additional storage bin should be easily covered by the reduction in the cost of the concrete and the added benefits to the concrete. Low-carbon fly ash or the use of a *better air-entraining agent at a higher-than-usual addition rate* can control the problem of *freeze-thaw durability*.

2.9.1 Advantages in Fresh Concrete:

Since fly ash particles are spherical and in the same size range as portland cement, a reduction in the amount of water needed for mixing and placing concrete can be obtained. In precast concrete, this can be translated into better workability, resulting in sharp and distinctive corners and edges with a better surface appearance. This also makes it easier to fill intricate shapes and patterns. Fly ash also benefits precast concrete by reducing permeability, which is the leading cause of premature failure. The use of fly ash can result in better workability, pumpability, cohesiveness, finish, ultimate strength, and durability. The fine particles in fly ash help to reduce bleeding and segregation and improve pumpability and finishing, especially in lean mixes.

2.9.II Advantages in Hardened Concrete:

Strength in concrete depends on many factors, the most important of which is the ratio of water to cement. Good quality fly ash generally improves workability or at least produces the same workability with less water. The reduction in water leads to improved strength. Because some fly ash contains larger or less reactive particles than portland cement, significant hydration can continue for six months or longer, leading to much higher ultimate strength than concrete without fly ash.

There have been several cases in which the early strength of concrete was low, particularly where a significant portion–30 percent or more–of the portland cement was replaced with fly ash. This need not be a serious problem today, since set time is also controlled by many other factors that can be altered to compensate for added fly ash, if necessary.

The observed slow set and low early strength obtained with fly ash has caused a reduction in the amount of this mineral admixture used in concrete. Although some fly ash materials will reduce early strength and slow the setting time it does not have to be the case today. Some fly ash actually accelerates set. The addition of accelerators, plasticizers and/or a small amount of additional CSF, as well as the proper beneficiated fly ash, can mitigate this problem.

Properly proportioned concrete containing fly ash should create a lower cost. Because of the reduced permeability and reduced calcium oxide in properly selected fly ash, it should be less susceptible to the alkali-aggregate reaction. Sulfate and other chemical attacks are reduced when fly ash is added. Fly ash, which has little effect on creep, has been suspected of contributing to corrosion because it reacts with the calcium hydroxide. Fly ash, in fact, does not materially reduce alkalinity, and the reduced permeability helps to protect the concrete from chloride penetration, the cause of rebar corrosion (see Rosenberg's article on corrosion in the Fall 1999 issue of MC Magazine). A superplasticizer combined with fly ash can be used to make high-performance and high-strength concrete. Concrete containing fly ash generally performs better than plain concrete in drying shrinkage tests.

2.10 Disadvantages of Fly Ash:

I The quality of fly ash is important–but it can vary. Poor-quality fly ash can have a negative effect on concrete. The principle advantage of fly ash is reduced permeability at a low cost, but fly ash of poor quality can actually increase permeability. Some fly ash, such as that produced in a power plant, is compatible with concrete. Other types of fly ash must be beneficiated, and some types cannot be improved sufficiently for use in concrete.

II. Some concrete will set slowly when fly ash is used. Though this might be perceived as a disadvantage, it can actually be a benefit by reducing thermal stress. When cement sets, it produces 100 calories per gram so that the temperature of a structure may rise 135 degrees. Certain fly ash can be used to keep the temperature from rising too high (less than 45 degrees). However, concrete with fly ash can set up normally or even rapidly, since many other factors control the set and strength development.

III. Freeze-thaw durability may not be acceptable with the use of fly ash in concrete. The amount of air entrained in the concrete controls the freeze-thaw durability, and the high carbon content in certain fly ash products absorbs some air entraining agents, reducing the amount of air produced in the concrete, making the concrete susceptible to frost damage. High-carbon fly ash materials tend to use more water and darken the concrete as well. It is not recommended to use a high-carbon (greater than 5 percent) content fly ash, but if it must be used, the proper air content can be reached by increasing the dosage of an air-entraining agent.

IV. Slow set and low early strength need not be consequences of using fly ash. Most of the time, high- fineness and low-carbon fly ash will result in high early strength. Sometimes, additional lime, an accelerator or a superplasticizer will be needed. Fly ash also can be mixed with a small amount of condensed silica fume (CSF) to improve set or early-strength properties. Certainly, careful attention to the mix design and water content is always necessary to obtain proper set and early strength development.

V. Precasters should try to obtain fly ash with as high a silica content as possible. Silica reacts with lime from cement to produce strength and reduce permeability (class F fly ash should have 50 percent silica content; class C should have 35 percent silica content). Water requirement be less than the control, that the color, density and fineness have a minimum variation (<5 percent) and that the strength activity index at 3, 7 and 28 days be 90 percent of the control. If protection from the alkali aggregate reaction is needed, then the fly ash should be tested in ASTM C 441 with 25 percent of the cement replaced with the fly ash. Some class C fly ash will not protect against the alkali-aggregate reaction. Lastly, it is important for the precast concrete producer to test the mix design continually, because fly ash is a group of materials that comes from burning coal.